LCA Case Studies

Life Cycle Assessment of Water from the Pumping Station to the Wastewater Treatment Plant

Stéphane Lassaux*, Robert Renzoni and Albert Germain

University of Liège, Laboratory of Industrial Chemistry, Allée de la Chimie, B6, 4000 Liège, Belgium

* **Corresponding author** (St.Lassaux@ulg.ac.be)

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Abstract

Goal, Scope and Background. The goal of this study is to determine the environmental impact of using one cubic metre of water in the Walloon Region. The whole anthropogenic water cycle is analysed, from the pumping stations to the wastewater treatment plants. The functional unit has been defined as one cubic metre of water at the consumer tap. This study was carried out in the context of the EU Water Framework Directive. It is part of a programme called PIRENE launched by the Walloon Region to fulfil the requirements of this Directive.

Methods. A model of the whole anthropogenic water cycle in the Walloon Region was developed. The model is mainly based on site-specific data given by the companies working in the field of water production and wastewater treatment. It was used to assess the environmental impact from the pumping station to the wastewater treatment plant using the Eco-Indicator 99 methodology. Eco-Indicator 99 has been adapted in order to better take into account environmental impact of acidification and eutrophication. Characterisation factors have been calculated for COD, nitrogen and phosphate emissions. From the reference model, different scenarios have been elaborated.

Results and Discussion. On the basis of the inventory, the environmental impact of five scenarios has been evaluated. Acidification and eutrophication is the most important impact category. It is mainly caused by the wastewater that is discharged without any treatment, but also by the effluent of the wastewater treatment plant. So, this impact category has the lowest environmental load when the wastewater treatment rate is high. For the other impact categories, the impact generally increases with the wastewater treatment rate. During wastewater treatment, energy and chemicals are indeed consumed to improve the quality of the final outputs, and thus to reduce the environmental impact related to acidification and eutrophication. A comparison between the scenarios has also shown that the building of the sewer network has a significant contribution to the global environmental load and that the stages before the tap contribute less to the environmental impact than the stage after the tap.

Conclusions. The three stages that contribute significantly to the global environmental load are: water discharge, wastewater treatment operation and, to a lesser extent, the sewer system. The results show that the wastewater treatment rate must be as high as possible, using either collective or individual wastewater treatment plants. Even a small water discharge without any treatment has a significant environmental impact. Operation of the wastewater treatment plants must also be improved to reduce the environmental impact caused by the effluent of the plants. For new wastewater treatment plants, building plants treating nitrogen and phosphorus should be encouraged. A sensitivity analysis was conducted and showed that the results of the study were not very affected by a modification of key parameters. Impact assessment using the CML methodology has confirmed the results obtained with Eco-Indicator 99.

Keywords: Anthropogenic water cycle; environmental impact; life cycle assessment; wastewater treatment plant; water

Introduction

In 2000, the EU Water Framework Directive was adopted. This directive sets ambitious objectives to ensure that all waters (rivers, lakes, coastal waters and groundwaters) meet a 'good status' by 2015. To achieve the requirements of this Directive, a programme called PIRENE (Programme Intégré de Recherche ENvironnement-Eau) was conducted by 18 teams from different Universities and Research Laboratories from the Walloon Region in Belgium. The goal of this programme was to develop the necessary tools for the Walloon Region to ensure an integrated management of water. Our team was in charge of the life cycle assessment of water. Some data give an illustration of the complexity of this task: more or less 400 million cubic metres of water are pumped each year in the Walloon Region, more than 100 wastewater treatment plants are in use.

Life cycle assessment has already been used to study particular processes of the anthropogenic water cycle, mainly in the field of wastewater treatment and sewage sludge management. Tillman et al. [1] analysed different alternatives for municipal wastewater systems for two cities in Sweden. A study of Hospido et al. [2] showed that water discharge and sludge application to land are the main contributors to the environmental load of a municipal wastewater treatment plant. Concerning sewage sludge, Suh et al. [3] presented a comparison of alternative wastewater sludge treatment scenarios. This point was also developed by Houillon et al. [4] who compared six wastewater sludge treatment scenarios (agricultural spreading, fluidised bed incineration, wet oxidation, pyrolysis, incineration in cement kilns and landfill) focussing on energy and emissions contributing to global warming. There are very limited references considering the whole water cycle from the pumping station to the wastewater treatment plant. Balkema et al. [5] tried to identify sustainable treatment options for domestic water including water supply in their system boundaries, but it was done indirectly by offering the possibility to use different water qualities.

1 Goal and Scope

The goal of this study is to determine the environmental impact of using one cubic metre of water in the Walloon Region from the pumping station to the wastewater treatment plant. The function is production, distribution and treatment of water in the Walloon Region. The functional

unit is defined as 1 cubic metre of water at the tap of the consumer. The analysed processes are:

- Water catchment (from ground and surface waters)
- Water treatment
- Water supply
- Sewer system
- Collective and individual wastewater treatment plant
- Wastewater sludge treatment
- Water discharge (without treatment)

For each of these processes, building and operation of the installations are studied. After evaluation of the environmental impact of a reference scenario, it will be possible to develop other scenarios reflecting different management options.

2 Description of the System

The reference scenario is based on data coming, on one side, from the companies working in the sector in the Walloon Region (water producers and suppliers, wastewater plants, ...) and, on the other side, directly from the Walloon Region public offices. The reference year is the year 2000.

2.1 Water balance in the Walloon Region

It is necessary to establish a balance of water flows in the Walloon Region in order to determine equivalent volumes for each stage of the water cycle. One cubic metre of water at the production is indeed not equal to one cubic metre at the tap. There are leaks during the water supply and there are also unregistered flows (e.g. for the fire department). Similarly, the consumption of one cubic metre of water at the tap doesn't mean that one cubic metre will be treated in the wastewater treatment plant (WWTP).

The water flow balance in the Walloon Region for the year 2000 (data mainly from [6]) lies at the basis of a diagram (**Fig. 1**) representing volumes equivalent to one cubic metre at the tap for each stage of the water cycle. Thus, on this diagram, it's possible to see that it's necessary to catch 2.47 cubic metre of water to finally have 1 cubic metre at the tap, but that an important part of the water extracted is exported to other regions in Belgium. After the tap, the major part of the water (0.78 cubic metre) is going to the sewer system. However, only a part is collected (0.70 cubic metre) and only a small part is treated in a wastewater treatment plant (0.29 cubic metre). The rest, except 0.01 cubic metre which goes to an individual wastewater treatment plant (Indiv. WWTP), is not treated, and directly rejected in the ecosystem. Besides wastewater, other types of water, like rainwater, are flowing through sewers and wastewater treatment plants. This contribution is taken into account and is represented in grey on Fig. 1.

The different processes on this diagram are presented in the next paragraphs.

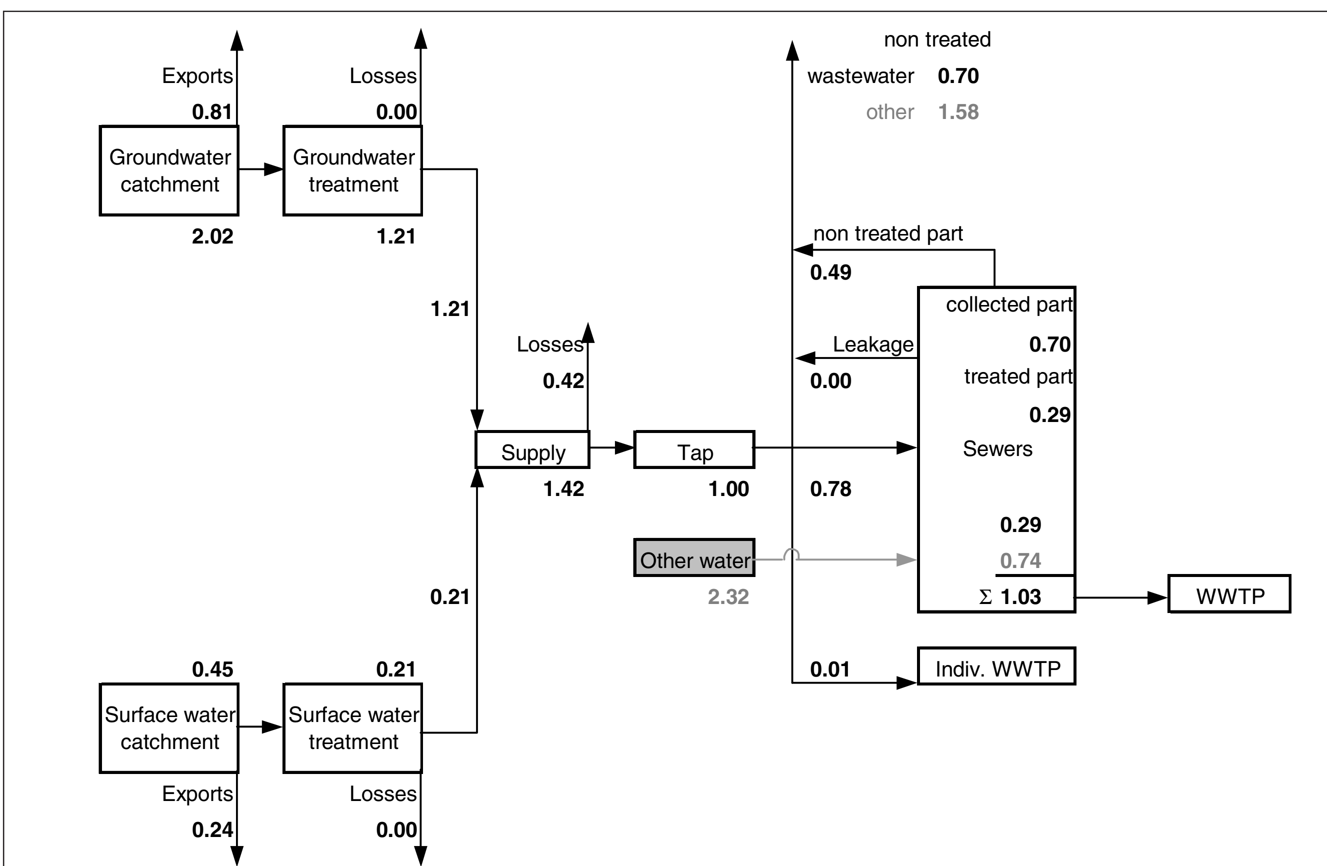

Fig. 1: Water flow balance relative to one cubic metre at the tap in Walloon Region

2.2 Water catchment

The water distributed in the Walloon Region is mainly coming from groundwater. It is generally pumped in wells or galleries that are old and sometimes built directly in the rock. Data for the building of these installations are poor and we have estimated roughly that this impact was equal to one tenth of the impact linked to the building of the dams used for catchment of surface water. Operation of the groundwater catchment plants is also not easy to estimate. Water producers are generally also managing the treatment and the supply of water. Operation of the plants is thus based on global electricity consumptions (catchment + treatment + supply) that were given directly by water producers or via Aquawal (Aquawal gathers together the main water producers-suppliers and all the wastewater and sewage treatment operators in the Walloon Region). Average electricity consumption was estimated at 0.39 kWh per cubic metre on the basis of data collected for catchment, treatment and supply of 208 million cubic metre of water during the year 2000. Allocation of electricity consumption between the three stages was estimated as follows: 45% for catchment, 10% for treatment and 45% for supply.

Production of water from surface water represents smaller volumes. Water is mainly supplied from 4 dams. Data on their building and operation are available. Dams are used to supply water but also generate electricity. Electricity production is accounted by system extension. These data are listed in **Table 1**.

Table 1: Data for production of water from surface water

Dam	Concrete (m^3/m^3)	Rockfill (kg/m^3)	Electricity production (kWh/m^3)
Gileppe	4.43E-04	5.61	0.25
Vesdre	3.53E-04	0	0.27
Ourthe	5.93E-05	0	0.75
Ry de Rome	0	4.68	0

2.3 Water treatment

For groundwater, there are four different categories of treatment, depending on water quality (A0: no treatment, A1: disinfection with chlorinated product, A2: light physico-chemical treatment and disinfection, A3: physico-chemical treatment and disinfection). Data were collected for all these categories and related to the volumes of water supplied by these different types of plants during the year 2000.

Surface water always needs to be treated. Detailed consumption data for the treatment plants associated with the four dams studied were provided.

Table 2 summarizes the average consumption of different chemicals used for groundwater and surface water treatment respectively.

The building of the water treatment installation is modelled on the basis of data collected for one important surface water treatment plant. These data are also used to estimate the environmental impact for building groundwater treatment plants.

2.4 Water supply

Energy consumption for water supply is estimated as a part of the global electricity consumption (45% as previously explained) for groundwater supply and is well known for surface water supply (0.25 kWh/m^3). Thus, we have the main contribution for operation of water supply.

In the case of water supply, the building of the whole infrastructure has probably an important impact. It is very difficult to have complete data for the whole infrastructure that represents more than 38,000 kilometres of pipes. We have collected complete data (length, diameter and material) for 961 kilometres of supply main waterworks and for 1,901 kilometres of service main waterworks. The environmental

Table 2: Chemical consumption for groundwater and surface water treatment

Chemical	Consumption Groundwater treatment (kg/m^3)					Consumption surface water treatment (kg/m^3)
Treatment	A0	A1	A2	A3	Average consumption	
Water volume (m^3)	10,000,000	260,000,000	40,000,000	4,400,000		
NaOCl (15%)	–	2.96E-04	4.19E-04	7.79E-04	2.16E-03	2.45E-02
NaOH	–	–	5.44E-03	–	6.92E-04	2.96E-03
Polyphosphates	–	–	2.44E-03	–	3.10E-04	–
Magno	–	–	1.02E-03	–	1.30E-04	–
Hydrocarbonate	–	–	5.01E-04	–	6.38E-05	–
$CaCO_3$	–	–	5.01E-05	–	6.38E-06	1.97E-02
$Ca(OH)_2$	–	–	1.00E-04	1.22E-02	1.83E-04	5.50E-02
Na_2CO_3	–	–	2.51E-04	–	3.19E-05	–
WAC	–	–	–	1.59E-03	2.23E-05	–
CO_2	–	–	–	8.11E-03	1.14E-04	5.88E-02
$Al_2(SO_4)_3$	–	–	–	1.83E-03	2.56E-05	7.65E-02
$FeCl_3$ (40%)	–	–	–	–	–	1.30E-02
Cl_2	–	–	–	–	–	3.30E-05
Polyacrylamide	–	–	–	–	–	1.74E-04
$KMnO_4$	–	–	–	–	–	7.83E-04
Activated carbon	–	–	–	–	–	1.65E-07

Table 3: Average mass of material required per km of pipe

Material	Average mass for supply main pipes (kg/m)	Average mass for service main pipes (kg/m)
Steel	201.9	37.0
Cast iron	76.1	17.6
Polyethylene	25.5	3.4
Polyvinyl chloride	7.4	2.7
Asbestos cement	16.6	13.0

impact of building the whole infrastructure is calculated on the basis of the mass of material needed to produce the pipes. These data are compiled in **Table 3**. Environmental impact of putting the pipes into ground is not taken into account.

2.5 Sewer system

It has been considered that the sewer system is completely gravity-powered. In this way, energy use for the whole wastewater treatment (sewer system and wastewater treatment plants) is completely allocated to the wastewater treatment plants. The environmental impact related to the sewer system is thus only related to its building phase. Data covering the whole sewer system in the Walloon Region were given by SPGE (Société Publique de Gestion de l'Eau). Unfortunately, diameters and materials for building the sewer were not available. Thus, we assumed that sewer pipes were only concrete ones and that their diameter was 500 mm for sewers (total length: 5,622 km) and 800 mm for main sewers (total length: 735 km).

2.6 Collective wastewater treatment

The inventory relating to the building of the collective wastewater treatment plants (WWTP) is based on detailed data relative to the amount of concrete, steel and sand that was necessary to build two recent plants.

For plants operation, we received data covering almost totally every plant in the Walloon Region. The wastewater treatment plants are classified in different categories depending on their capacities and their characteristics. For all these wastewater treatment plants, we considered not only energy consumption, but also lime, iron chloride and polymers consumption when these chemicals were used in it. **Table 4** presents the categories, the number of plants represented for each category and an average for electricity and chemical consumption.

After treatment, water is rejected into the river. Typical outputs of wastewater treatment plants were measured (COD, N Kjeldahl, etc.) to determine the environmental impact (**Table 5**). Wastewater treatment plants also produce sludge. This point is discussed in another paragraph.

Table 5: Average outputs for each category of wastewater treatment plants in Walloon Region (mg/l)

Type	COD	N Kj	N-NH_4	N-NO_3	P-PO_4
1	40.80	11.01	4.62	7.53	2.93
2	47.74	4.91	1.07	5.89	1.60
3	41.97	12.56	6.19	10.96	3.18
4	25.83	3.90	1.04	5.42	1.30
5	24.25	11.31	8.21	1.43	1.67
6	40.13	7.54	3.35	13.05	2.38
7	27.07	4.71	2.27	5.83	0.98
8	38.95	13.77	8.51	2.22	1.96
9	41.37	8.71	3.66	13.27	2.49
10	43.11	6.81	2.88	7.97	1.74
11	49.74	12.59	7.03	2.71	1.79

Table 4: Average consumption of electricity and chemicals for each category of wastewater treatment plants in Walloon Region

Type	Category	Number of WWTP	Treated volume (%)	Electricity (kWh/m^3)	Iron chloride (40%) (kg/m^3)	Polymers (kg/m^3)	Lime (kg/m^3)
1	WWTP with a capacity above or equal to 50 000 inhabitant equivalent (IE)	3	16.52	0.31	–	2.56E-4	1.30E-2
2	WWTP with a capacity above or equal to 50 000 IE treating nitrogen and/or phosphorus	3	20.01	0.28	2.71E-3	4.78E-4	3.01E-6
3	WWTP with a capacity between 10 000 and 50 000 IE	14	14.77	0.33	7.80E-5	4.93E-5	-
4	WWTP with a capacity between 10 000 and 50 000 IE treating nitrogen and/or phosphorus	11	15.53	0.31	1.23E-4	1.86E-4	1.74E-2
5	WWTP with a capacity between 10 000 and 50 000 IE with lagooning	1	1.21	0.25	–	–	–
6	WWTP with a capacity between 2 000 and 10 000 IE	54	14.47	0.36	–	8.75E-5	–
7	WWTP with a capacity between 2 000 and 10 000 IE treating nitrogen and/or phosphorus	7	2.55	0.29	–	–	–
8	WWTP with a capacity between 2 000 and 10 000 IE with lagooning	7	4.11	0.11	–	–	–
9	WWTP with a capacity under or equal to 2 000 IE	162	9.26	0.36	–	–	–
10	WWTP with a capacity under or equal to 2 000 IE treating nitrogen and/or phosphorus	4	0.28	0.40	–	–	–
11	WWTP with a capacity under or equal to 2 000 IE with lagooning	14	1.30	0.19	–	–	–

2.7 Individual wastewater treatment

In rural areas where a collective sewer system would be too expensive to install, people have to install their own wastewater treatment plant before 31 December 2009. These systems are not very common, but they must receive an agreement from the Walloon Region. Thus, their technical characteristics are available. These systems are mainly built in concrete and we have assumed, on the basis of the technical data available, that the amount of concrete used to build such a plant was 750 kg. We have also calculated that the energy consumption of an average system was 3.87 kWh/m^3. Effluent composition of these systems is determined by another PIRENE team (CEBEDEAU).

2.8 Wastewater sludge treatment

Secondary sludge produced by the wastewater treatment plants is used in agriculture, landfilled or incinerated.

Before agricultural spreading, sludge is generally limed. This operation consumes electricity and lime. These consumptions are evaluated on the basis of an environmental study realised by the French Water Agencies [7]. Agricultural spreading requires a substitution linked to the fertilisation provided by the sludge on agricultural land. Substitution is considered for nutrients (N, P, K) available in sewage sludge. Availability of nutrients in sludge is determined on the basis of sludge analysis (N: 40.36 kg/t DM, P: 41.27 kg/t DM and K: 4.81 kg/t DM). The processes to substitute are potassium nitrate and triple superphosphate production. Agricultural spreading has the drawback of spreading micro-pollutants on land. This effect is taken into account considering composition of sludge and of fertilisers (substitution).

Landfilling is modelled considering that 60% of the carbon content of the sludge is oxidised. This produces biogas, a part of which is burned in engines (50%). Another part (20%) is flared and the rest of the biogas is emitted directly into the atmosphere. Emission data for the flare and the engines are available [8]. Electricity produced by the engines is taken into account considering the Belgian electricity mix. Water effluents of the landfill are treated by a wastewater treatment plant. Its effluent composition is calculated as an average of the plants presented in paragraph 2.6.

A small part of the sludge is incinerated in a single installation. The fuel consumption is evaluated at 270 kg per ton dry matter. Flue gas emissions values of this installation are available [9].

2.9 Water discharge

A great part of the wastewater is still discharged in the environment without any treatment. It is thus important to evaluate its impact. However, there are few data about this subject. Thus, it has been considered that the average composition of this flow was equal to the well-known average composition of the input of the wastewater treatment plants.

3 Definition of Other Scenarios

From the reference scenario (called 2000) that has been detailed here above, it is possible to develop other scenarios.

3.1 Scenario 2004

In this scenario, the connection rate to a wastewater treatment plant has been estimated to 47% reflecting the efforts made between the year 2000 and the year 2004.

3.2 Scenario 2015

In this scenario, the wastewater treatment plan of the Walloon Region is achieved (year 2015) and the connection rate to a collective wastewater treatment plant is 92% while the connection rate to an individual system is 6%. The whole sewer system is also finished.

3.3 Scenario without WWTP

This scenario gives an idea of the environmental impact without wastewater treatment plants.

3.4 Scenario 50 000 IE N/P

In this scenario, the average wastewater treatment plant is replaced by a modern one with a capacity above or equal to 50 000 IE and treating nitrogen and phosphorus.

4 Inventory

The inventory is mainly based on data coming from existing installations for the year 2000. Data were given by the water producers and the companies working in wastewater treatment in the Walloon Region or via Aquawal, but also by the Walloon Region offices directly. Data used are often averages for one particular type of installation and are described in section 2. Thus, we assumed that they are of good quality and highly representative of the Walloon Region. Data for chemicals are mainly coming from existing databases (mainly Ecoinvent), from literature or from theoretical calculations.

5 Impact Assessment

On the basis of the inventory, the environmental impact of the five scenarios has been evaluated using Eco-Indicator 99 [10,11]. The following categories have been studied:

- Carcinogenic effects
- Respiratory effects caused by organic substances
- Respiratory effects caused by inorganic substances
- Climate change
- Ecotoxic emissions
- Acidification and eutrophication
- Extraction of minerals
- Extraction of fossil fuels

Water is here considered as a product, but it is also an abiotic fund resource that has to be protected. In the case of fund resources, natural replenishment may avoid or slow down depletion. At the level of the Walloon Region, the amount of groundwater available each year is estimated at 550 millions of cubic metres. So, the use of this resource is clearly not a problem at this moment and impact assessment of water resource consumption was not taken into account.

Table 6: Characterisation factors for COD, nitrogen and phosphate emissions

Substance	Characterisation factor (PDF*m2*yr)
COD	1.62
N	32.61
P	225.44

Eco-Indicator 99 has been adapted to better take into account environmental impact of eutrophication. Thus, characterisation factors have been calculated for COD, nitrogen and phosphorus emissions using the eutrophication potential factors presented in CML [15] and adapting them to match the existing factors available in the Methodology Annex of Eco-indicator 99 [11]. This is a very rough estimation of the characterisation factors, but we estimated it was better to use these factors rather than ignoring this important impact category. The factors we used are listed in **Table 6**.

In principle, one nutrient is limiting the growth in an ecosystem [12]. Freshwater systems are generally limited by phosphorous and therefore, increase in nitrogen concentration will not affect the ecosystem [13,14]. So, only the values calculated for COD and phosphorus were used in this study.

Assessment of the environmental impacts is done in several steps (classification, characterisation, normalisation and weighting). The normalisation phase allows us to compare the environmental impacts on a same scale. The results after normalisation are discussed below.

Fig. 2 shows that acidification and eutrophication is the most important impact category. This figure presents indeed the results of the category acidification and eutrophication in a secondary axis with a scale 5 times higher. This impact is mainly caused by the wastewater that is discharged without any treatment, but also by the effluent of the wastewater treatment plant. This impact is dominating even in the 2015 scenario with the highest wastewater treatment rate. The high environmental load of the effluent of the wastewater treatment plant was already noticed in [2]. Respiratory effects caused by inorganic substances are mainly linked with an emission of particulate matter during the building of the sewer system.

Fig. 3 presents the same results on a relative scale. This figure makes it easier to compare the different scenarios for a same category. Thus, it can be noticed that scenario 2015 is always the worst scenario from an environmental viewpoint

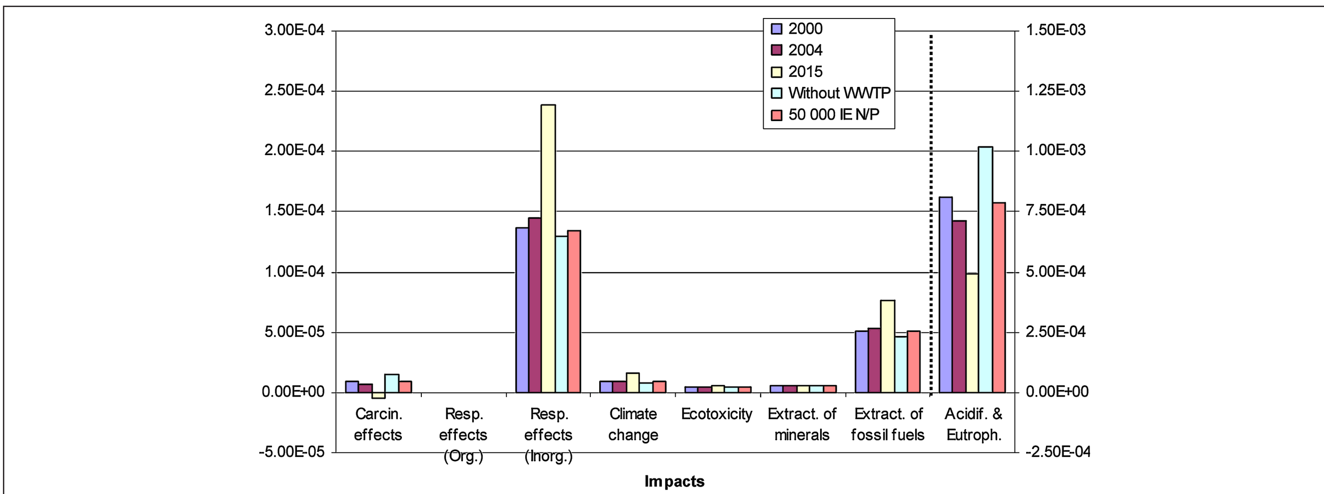

Fig. 2: Normalisation profiles for the five scenarios (the category Acidification & eutrophication is presented in a secondary axis)

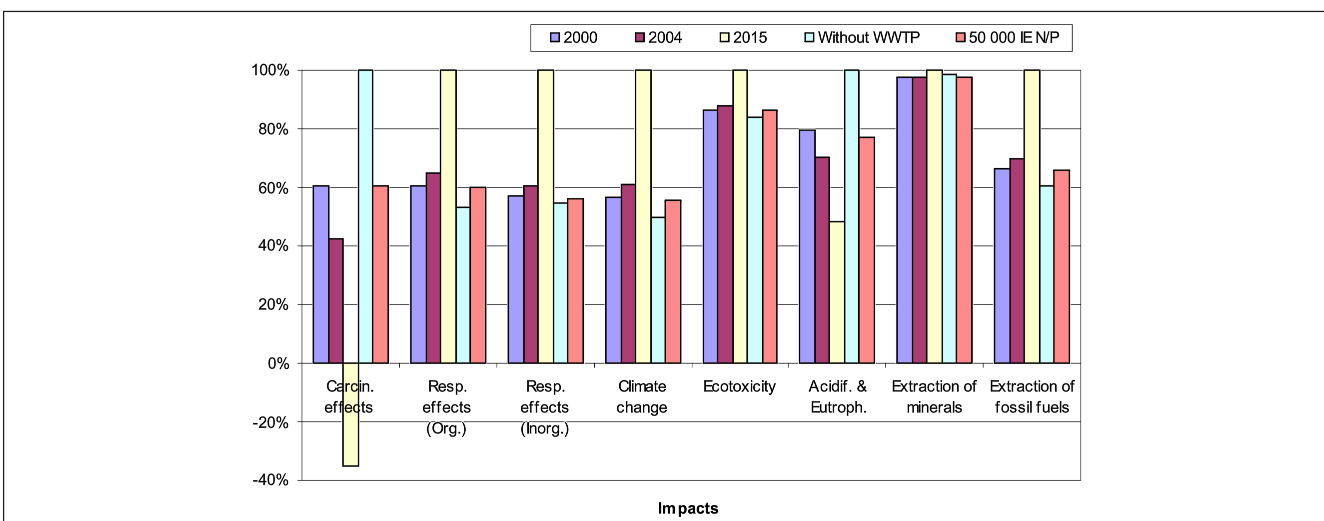

Fig. 3: Normalisation profiles on a relative scale

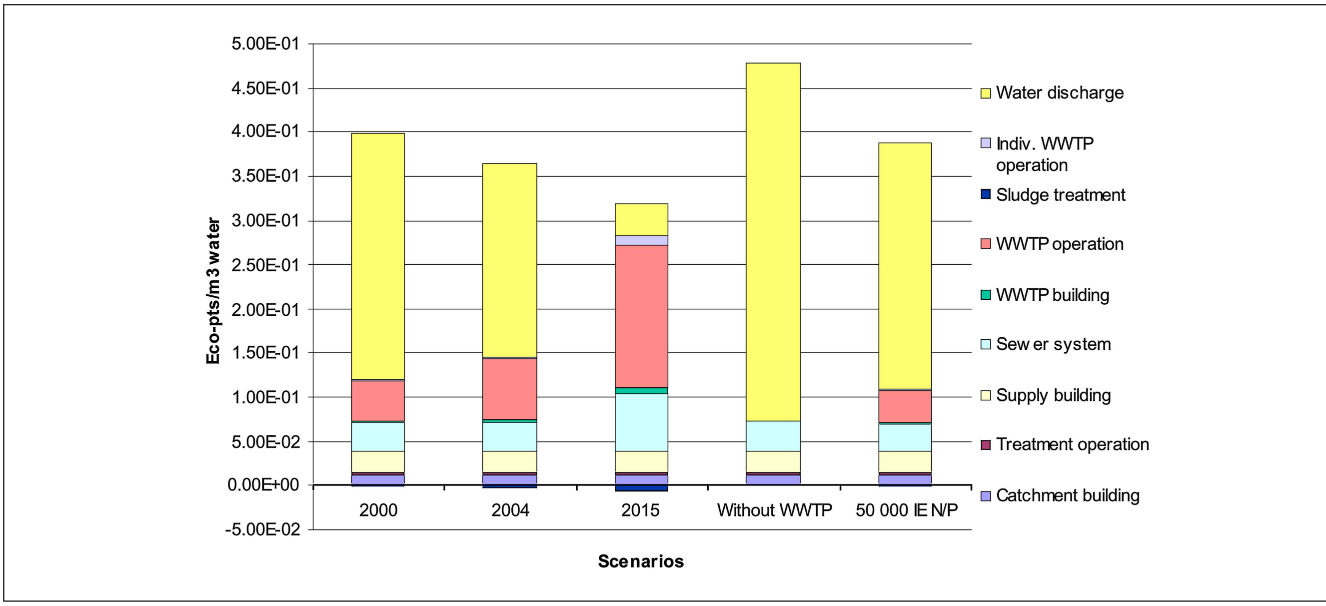

Fig. 4: Relative contribution of each stage to the global environmental load (Stages contributing less than 0.5% to the global environmental load are left out)

except for carcinogenic effects and acidification and eutrophication. This looks right because wastewater treatment needs energy and chemicals, which mainly have an environmental impact for all categories, to improve the quality of the final outputs and thus to reduce the environmental impact related to acidification and eutrophication. For the carcinogenic effects category, a negative value appears for the scenario 2015 traducing a small environmental saving. Spreading wastewater sludge in agriculture instead of using fertilisers implies two effects. On the one hand, some micropollutants coming from the sludge are added to the agricultural soils. On the other hand, some heavy metals present in fertilisers (like cadmium) aren't spread anymore. In this case, the second effect is predominant. However, uncertainty about this result is relatively high because data relative to heavy metals in wastewater sludge and in fertilisers are relatively poor.

It is generally recognised that the weighting step involves a high degree of subjectivity and it is therefore generally left out. Nevertheless, it is certainly interesting to have a global view of the environmental impact of each stage studied here and this is only possible by carrying out the weighting step. This step was done using the Hierarchist perspective with average weighting set (H,A) of Eco-Indicator 99 (default version).

The relative contribution of each stage to the global environmental load is presented in **Fig. 4.** For better reading, we excluded stages with an insignificant contribution (less than 0.5% of the global environmental load). These are: catchment operation, treatment building, supply operation and individual wastewater treatment plant building. It can be seen that the environmental load is mainly caused by water discharge in the environment without any treatment (dots pattern). In scenario 2015, this stage is no more dominating, but is still important if we consider that nearly all the water goes to a wastewater treatment plant. In this scenario, the stage of wastewater treatment plant operation (light upward diagonal pattern) contributes mainly to the global environmental load. The impact of this stage is mainly due to the release into the ecosystem of water already treated by the wastewater treatment plants. This effluent still contains COD and a lot of phosphate. The building of the sewer network also demonstrates a significant contribution (light downward diagonal pattern). It appears clearly that the stages before the tap also contribute less to the environmental impact than the stage after it (less than 8% of the global environmental impact in the worst case, i.e. scenario 2015).

These results highlight that the wastewater treatment rate must be as high as possible, using either collective or individual wastewater treatment plants. Even a small water discharge without any treatment has a significant environmental impact. Operation of the wastewater treatment plants must also be improved.

6 Sensitivity Analysis

A sensitivity analysis was conducted on different parameters that could influence upon the balance of the different scenarios.

6.1 Building of catchment and treatment plants for groundwater production

Data related to the building of catchment and treatment plants for groundwater are very scarce and, thus, have a relatively higher uncertainty. The sensitivity analysis was conducted considering the amount of concrete and sand to build these plants was 10 times higher. This important change doesn't influence the global balance between the scenarios

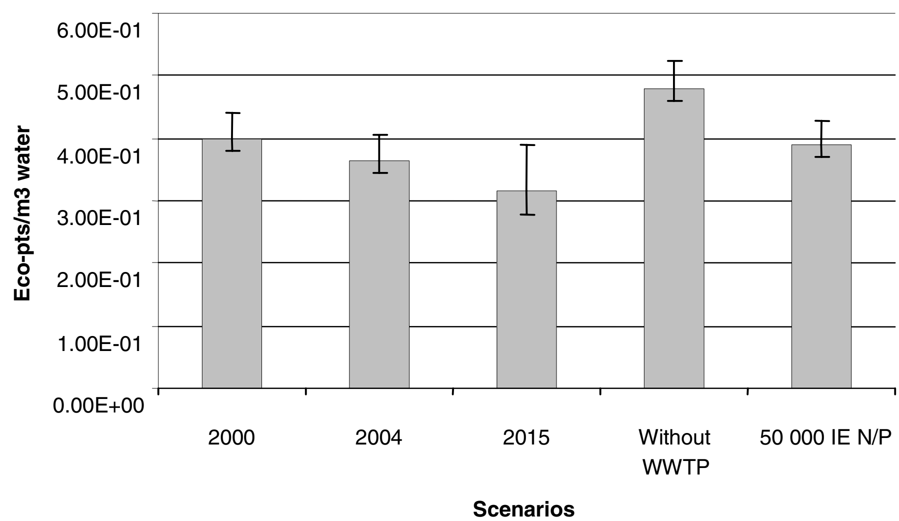

Fig. 5: Sensitivity analysis on sewers and main sewers diameter

and the additional contribution for this stage is very weak considering the global environmental impact.

6.2 Sewers and main sewers diameter

In first assumption, the diameter of the main sewers and of the sewer pipes has been set to 800 and 500 mm, respectively. During the sensitivity analysis, the results were re-evaluated, with the main sewer diameters varying from 500 to 1,000 mm and the pipes from 300 to 800 mm. These results are shown in **Fig. 5**, where the range of variation of the eco-score is materialised by error bars.

6.3 Method

The results of this study may also be influenced by the choice of the impact assessment methodology. So, the CML [15] methodology has been used to check the results obtained with Eco-Indicator 99. **Fig. 6** presents the results obtained after normalisation using the CML methodology. They can be compared with those presented in Fig. 2, showing the normalised results with Eco-Indicator 99. The results are very similar showing that the choice of the methodology has little effect on the eco-profile. It can just be noted that the CML methodology gives a higher importance to the impact category ecotoxicity. This fact was already mentioned in [16].

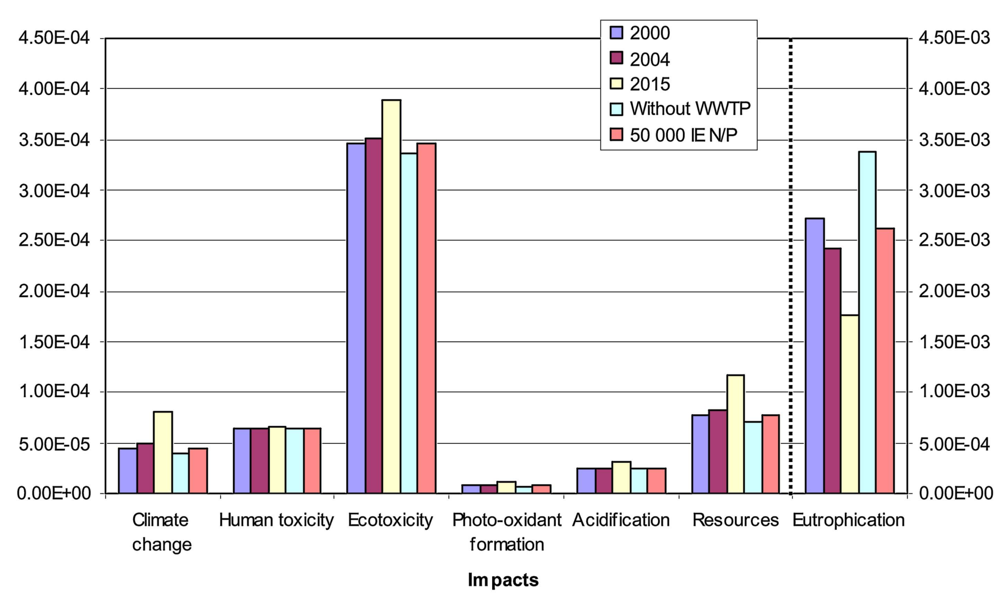

Fig. 6: Normalisation profiles using CML methodology (the category Acidification & eutrophication is presented in a secondary axis)

7 Conclusions

A model of the whole anthropogenic water cycle in Walloon Region was developed. This model, mainly based on site-specific data for the year 2000, was used to assess the environmental impact from the pumping station to the wastewater treatment plant. From this reference model, different scenarios have been elaborated. The comparison of these scenarios has shown that the global environmental load decreases when the wastewater treatment rate increases. This is mainly linked to the decrease of acidification and eutrophication, as this category has the main environmental impact. Impact for other categories generally increases with the wastewater treatment rate due to higher energy and chemicals consumption. Main contributions to the global environmental load have been identified. Stages that contribute a lot to the global environmental load are: water discharge, wastewater treatment operation and to a lesser extent sewer system building.

In order to minimise the global environmental load of the whole anthropogenic water cycle, it is thus more interesting to concentrate first on the stages after the tap. Having in mind that even small water discharges without any treatment have a significant impact, the wastewater treatment rate should be as high as possible. It is also important to improve the effluent quality of the actual and future wastewater treatment plants. For the new wastewater treatment plants, building of plants treating nitrogen and phosphorus should be encouraged.

A sensitivity analysis was conducted and showed that the results of our study were not very affected by a modification of key parameters. Impact assessment using the CML methodology has confirmed the results obtained with Eco-Indicator 99.

Some uncertainties have been pointed out. Data for the building stage of the installations are not as complete as for operation (mainly for water catchment and water treatment). For the sewer system, only data relative to the length of the pipes are available. Data about heavy metal in the influent and in the effluent of the wastewater treatment plants are not available so that a balance of these heavy metals is not possible. At this moment, site-specific data relative to individual wastewater treatment plants are poor.

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